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1. Theoretical and Experimental Program on the F Region Utilizing Arecibo Data

J. S. Nisbet, J. Doupnik, D. McCrory, M. Kwei

1.1 F-region Processes

During this report interval several problems related to the photoelectron flux in the ionosphere and exosphere and the heating of the F region have been studied.

Trapping of the photoelectrons by inelastic collisions appears to be extremely important in the F region because the neutral collisions continually direct the photoelectrons into paths having a small translational component. In general also there is a net upward flux produced because the electrons traveling in the upward directions move further before making a collision than those traveling downward. It is not correct, however, to characterize this flux as an "escape" flux because most of the energy is lost locally.

I have attempted to calculate the mean upward motion $\bar{x}$ per collision for the trapped component and an escape probability. I obtained for this mean upward motion

$$\bar{x} = \lambda a \left[\frac{C}{2} (e^a + \log a) - \frac{3}{4} a^2 - \frac{25}{288} a^4 - \frac{147}{4320} a^6 + \frac{2283}{33,868,800} a^8 - \frac{7381}{914,457,600} a^{10} \ldots \right]$$

where C = Euler's constant

λ = the mean free path for elastic collisions

a = $H/\lambda \sin I$ when λ is the scale height of the neutral atmosphere.

Tables have been calculated by Divany which allow average values of this function to be calculated over the angular spread of the photoelectrons. These values were then used to calculate electron fluxes and lifetimes. The escape probability is quite a complicated problem because of the losses to the ambient electrons and inelastic collisions. If the probability of making an inelastic collision is q then, if losses to the ambient electrons are neglected, the probability of making an escape collision in n collisions is

$$P_e = \frac{p}{p+q}\left[1 - (1 - p - q)^n\right]$$

where $p = \frac{1}{4}\left\{e^{-a} + a\left[C + \log a - a + \frac{a^2}{2.2!} - \frac{a^3}{3.3!} \cdots\right]\right\}$

C is Euler's constant

and $a = \frac{H}{\lambda \sin I}$

The problem can then be treated by allowing a number of increments in energy loss to ambient electrons by choice of a suitable n. In general for the photoelectrons of energy greater than 10 ev important to this problem it appears easier to use an average energy loss for each inelastic collision and to then recalculate the energy loss and escape probabilities. Divany has developed a computer program and sent me the results for some of these calculations.

A useful expression for estimating the fraction of the local energy loss a photoelectron gives to the ambient electrons is

$$\frac{\varepsilon_e}{\varepsilon_o} = e^{-b\,\varepsilon_c^2}\left[1 + \frac{b\,\varepsilon_o^2}{3.1!} + \frac{(b\,\varepsilon_o^2)^2}{5.2!} + \frac{(b\,\varepsilon_o^2)^3}{7.3!} \cdots\right]$$

when $b = \frac{\Sigma q_m n(M)}{3.9 \times 10^{12} n_e}$

For electrons in the 8 to 20 ev range the values calculated using this expression are quite close to those obtained using detailed cross sections and following these down through their energy loss processes.

I have been reading McCrory's and Widmaier's theses and working on some calculations relevant to these. A paper was prepared for presentation at the forthcoming Cospar meeting in Vienna.

J. S. Nisbet

1.2 Arecibo Data Analysis

Incoherent backscatter measurements of electron temperatures and densities and ion temperatures were made during four periods at Arecibo, one in October and three in December. Electron temperatures calculated from the data during the day showed large variations in a sense opposite to those of the densities. Peak electron densities were observed to fluctuate to twice their normal daytime values in a period of two or three hours.

Daytime electron temperatures increased with altitude at a rate of about 2° k/km above 225 km, and the electron to ion temperature ratio averaged about 2.4. The data are similar to those of the preceding winter, but they are of higher quality and have better time resolution.

Computer programs were written to solve independently the electron density and temperature continuity equations as a function of time. These equations are to be solved simultaneously over a period of several hours or perhaps a day to examine the observed coupling between densities and temperatures. Most of the work was concerned with the problems of numerical accuracy at high altitudes and of solution time.

J. R. Doupnik

1.3 Nighttime F Production

Data obtained at Arecibo, Puerto Rico in December 1964 raised the question of nighttime production. It was observed that during the nighttime, the electron content did not decrease and in fact did increase throughout a major portion of the night. Nisbet and Carlson in a paper presented at the Spring 1965 URSI meeting attributed this phenomenon to photoelectrons traversing the field lines from the conjugate region and thus causing the observed increase in electron content.

At the present time, these same data are being used to try to arrive at the winter recombination coefficient for the nighttime hours by considering the day as a whole.

In December 1965, another trip was made to Puerto Rico and it is believed that three good days of data were obtained. These data are presently being processed and will subsequently be used to determine winter nighttime recombination coefficients and to possibly corroborate the December 1964 findings concerning nighttime production.

Donald R. McCrory

1.4 Summer Recombination Coefficients

In June of 1965 a trip was made to Arecibo, Puerto Rico for the purpose of gathering incoherent backscatter data. Three weeks were spent at the site there but due to some equipment problems only one good day of data was obtained. These data have been analyzed and are, at the present time, being incorporated into my thesis and a scientific report. However, it is felt that more summer data will be required before any conclusive statements can be made.

Donald R. McCrory

1.5 F-Region Temperatures

The behavior of predawn electron temperature in December 1964 at Arecibo, Puerto Rico was investigated.

It was found that, in early morning in the sunlit conjugate region in travelling from the 300 km level to the 600 km level, a photoelectron with an initial energy greater than 5 ev loses only a negligible amount of energy to the ambient electrons for all pitch angles up to about 80°. The minimum amount of energy required for the photoelectron to reach the Arecibo end of the field line was found to be about 6 ev. However, the photoelectrons with an initial energy greater than 15 ev loses only a small percentage of its initial energy to the electron gas along the field line in this considerable trajectory for all pitch angles up to 70°.

An equation for the photoelectron flux escaping from the sunlit conjugate region was developed. When reaching the Arecibo end of the field line the photoelectrons will be gradually scattered out of the flux upon the first collision with the neutrals in the dark ionosphere and assume random trajectories. An equation was derived for the production rate of these photoelectrons in a random walk or the loss rate of the incoming unscattered photoelectrons. It appears that most of the incoming photoelectrons would be scattered out of the beam above an altitude of 200 km in the dark ionosphere over Arecibo.

The possibility of backscattering from the dark ionosphere of the incoming photoelectrons from the sunlit conjugate region was investigated. Using the equation for the production rate of photoelectrons in a random walk, an equation was developed for the

backscattering photoelectron flux in the dark ionosphere.

It is hoped that an estimate of the incoming photoelectron flux and the heat input to the electron gas in the dark ionosphere over Arecibo, due to this incoming photoelectron flux, can be given in the next report. The heat input to the ambient electron gas in the dark ionosphere due to the heat conduction along the field line will also be investigated.

Three weeks were spent with J. Doupnik in December 1965 at the Arecibo Ionospheric Observatory making measurements of electron densities, electron temperatures and ion temperatures.

M. W. Kwei

2. M-D Rocket Program

2.1 Propagation Experiment

Within this past six months I have completed the analysis of the results from the Mother-Daughter Javelin 8.29 flight on May 19, 1965. The final electron density profiles, accurate to better than 1.5%, were closely examined for small-scale irregularities which appeared to be less than 2% over densities. Large scale horizontal gradients on the order of 10% over a theoretical uniform ionosphere profile was measured; and were centered near apogee of the flight. The cause of this E-W gradient was directly attributed to a magnetic field anomoly which was detected and measured by an onboard magnetometer. An extensive investigation into the sources of errors was also made for the profile as well as a comparison of our results with simultaneous experiments. The complete analysis is in my thesis and Scientific Report No. 263 which was just recently completed.

A computer program is currently being devised to facilitate

reduction of phase data to electron densities for future M-D flights.

J. Widmaier

2.2 M-D Probe Experiments

The last two experiments, in October 1965, failed due to a separation failure and a vehicle failure. No usable data were obtained.

The data from the successful shot of May 19, 1965, has been analyzed. The ion trap on the Mother observed the effects of the wake of the Daughter to about 100 meters separation. The ion trap was observed to cease to function according to simple theory at the altitude where the ion sheath became equal to the probe diameter. Vehicle potential was determined to be about -2 volts throughout the flight and this relatively high potential probably is responsible for a relatively high ion current collected on the downleg of the flight.

Work has commenced in the design of a second generation of probe experiments for F-region studies, utilizing the information obtained from the first series of M-D shots.

L. C. Hale

2.3 Deep Space Probe

The main purpose of the deep space probe is to measure ion densities in the region from 500 to 2000 km. The type of probe which will be utilized is the planar probe used in the previous M-D experiments.

The first problem considered was the selection of a vehicle. Calculations have been made and show that the Javelin rocket modified with an additional Arcas stage would be both capable and economically feasible.

Work is presently being conducted on ion collection to the probe

covered by a large sheath. Under this condition, simple probe theory does not hold. Poisson's equation was solved for the sheath covered probe. Particle trajectories are being determined under the following conditions:

1. The speed of the rocket is much greater than the speed of the ions.
2. No collisions occur inside of the sheath.
3. The electric is zero outside of the sheath.

Another problem which shall be considered in the future is particle collection in the wake of the rocket during descent.

Modifications are being made on existing probe electronics.

B. A. Pontano

3. Upper Atmosphere Electrodynamics

3.1 Magnetosphere Studies

A paper "The Transmission and Reflection of Electromagnetic Waves normally incident on a Warm Plasma" was submitted to Physics of Fluids. The paper was later revised and resubmitted (Accepted in March 1966).

In the last of August and first of September attended the NATO Advanced Study Institute in Bergen, Norway on "Particles Trapped in the Earth's Magnetic Field". A good portion of the past six months has been spent on looking at the relation of these phenomena to the low energy plasma behavior in the magnetosphere.

Work is in progress on a possible fluid-dynamic approach to Carpenters' knee in the magnetosphere.

C. Comstock

3.2 Magnetospheric Plasma Flow

Worked on a 3-dimensional equation of motion of a single charged particle through a dipole magnetic field, and arrived at a solution for one velocity component. The other velocity components and space coordinates are badly coupled.

Read an article concerning the influence of the earth's rotation upon the interaction of the solar wind with the magnetosphere, by E. W. Hones. The article consists of a feasibility study of a plasma injection mechanism on the midnight side of the earth, based on water-flow experiments.

E. C. Stevenson

4. Aerodynamic Theory

4.1 Upper Atmosphere Motions

Experimental studies of the statistical properties of high altitude turbulence as derived from electron density measurements, made at Arecibo, were continued. Two theoretical papers concerning this work are abstracted below:

"Dispersive Waves in the Upper Atmosphere"

Using a correlation technique, statistical properties of dispersive waves in the upper atmosphere are studied. Included are the mathematical description of the correlation technique, a simple example of how the correlation function for atmospheric waves behaves, and data from the radar at Arecibo, Puerto Rico. A rough correlation between the simple example and the data exists. But the data also show that other, as yet unidentified, dispersive waves are present. The intensity of these waves decreases markedly above 100 km.

"Random Dispersive Waves"

The physical theory of the detection and measurement of the intensity of random dispersive waves in the presence of noise is given. It is shown that a dispersive wave must travel a long distance from its source to be distinguishable from the background noise. Both the statistically stationary and a non stationary case are discussed.

The status of the papers relative to this work is outlined below:

Papers read:

"Random Dispersive Waves" at Symposium on Interactions between Upper and Lower Levels of the Ionosphere" 3-7 May, Vienna.

"Dispersive Waves in the Upper Atmosphere" May COSPAR, Vienna.

Papers accepted:

"Random Dispersive Waves", Phys. Fluids.

"First Order Corrections to D Region Probe Theory",J.G.R.

Papers published:

"Alfven Wave in an Incompressible Medium" Phys. Fluids December 1965.

D.P. Hoult

4.2 Gravity Wave Studies

First, a survey of the literature on gravity waves was made. The next step consisted of formulating a problem to determine how the gravity waves were coupled with fluctuations in electron density, that is, the tagging of the electrons to the fluid motion was studied. The proper initial values were chosen for this problem, and the corresponding solution was obtained. The solution of this problem

then yielded the proper dispersion relationship, and the appropriate correlation techniques were applied for random dispersive waves in order to observe the gravity waves.

Richard Warner

5. Accomodation Coefficient Studies

5.1 Surface Kinetic Studies

This program concerns a design study of a device to measure thermal accommodation coefficients. Such a facility would measure the low energy scattering phenomena when a neutral gas molecule with about 1/40 ev impinges on a solid surface. Knowledge of such processes is of fundamental importance in the operation of high altitude probes, as this scattering process forms the surface boundary condition for statistical mechanical equations of the plasma.

This study is presently being conducted along two lines. The first objective is the determination as to whether the state of the art in thermal and momentum accommodation coefficient measurement techniques can be measurably improved and adapted to the direct determination of incident and reflected particle distribution functions for a general class of gas-solid interactions.

A parallel theoretical investigation is being carried out which attempts to relax the classical assumptions in regard to theoretical predictions of accommodation coefficients, and is proceeding along quantum-mechanical lines.

D. P. Hoult
B. R. Carson

5.2 Gas-Surface Interaction

The earlier portion of the above period was spent in looking through reports and papers on a theory for the thermal accommodation coefficient. It is found that the theories presented are semi-classical in nature, which agree only qualitatively with published experimental data. This disagreement could, in part, be attributed to the nature of the experiments themselves, where a number of uncontrollable factors arise, making it impossible to obtain measurements under ideal conditions.

However, a certain need for improvement in the theoretical analysis of the problem was felt, and preliminary steps were taken in this direction. A quantum mechanical model was envisaged to yield better results for the interaction of gas molecules with the surface of a metal. A preliminary calculation was made for the electron energy levels in a semi-infinite solid with a highly idealized potential distribution. A similar problem with further simplification using a δ-function potential distribution has been described by P. Pharisean in a series of papers in Physics. The next step will be to assume an interaction potential for the gas molecule and surface atom model.

S. N. Basrur

6. Langmuir Probe Theory and Experiments

6.1 Langmuir Probe Theory

The work on the subsonic, blunt D-region probes was summarized in an article "First Order Corrections to D Region Probe Theory" to appear in JGR, July 1966. The major conclusions are:

"The largest corrections are due to heat transfer and compressibility. These corrections tend to cancel each other for small angles of attack. The largest correction is due to heat transfer, and is at most ten percent. The first order theory, uncorrected, is valid to within ten percent."

A scientific report is being prepared comprising and unifying the three previous papers "Weak Shock Waves", "D Region Probe Theory" and "First Order Corrections to D Region Probe Theory".

T. Kuo
L. C. Hale
D. P. Hoult

6.2 D-Region Experiments

Over a period of two years, eleven meteorological rockets have been launched with parachute borne blunt probes to measure charged particle parameters in the altitude range 40 to 80 km. Six successful launches have been made at night, with the data showing close repeatability between 50 and 63 km. The two most recent night shots, on January 5, 1966, utilized an improved version of the experiment which removes the ambiguity of interpretation of earlier data.

The blunt probes used collect charged particles according to the theory of Hoult. This theory predicts a probe current independent of angle of attack and linearly proportional to probe potential, both of which are observed. The most recent experiments used a return electrode very much larger than the probe, consisting of the silvered parachute and silvered shroud lines. This enabled the separation of the positive and negative charged particle conductivities. It was found that over the altitude range of 50 to 63 km. the negative

conductivity exceeded the positive conductivity by about 25%. This is consistent with laboratory measurements of the ratios of mobilities of small negative and positive ions. Assuming a small ion model it is concluded that the electron density was very small. In particular λ, the negative ion to electron ratio, must have been in excess of one thousand over the altitude range 50 to 63 km. and greater than 330 at 77 km. It is concluded that collisional detachment is a relatively unimportant process in this situation.

Using assumed values of mobility and a model of the atmosphere, positive and negative ion densities may be deduced. Below 63 km. the resulting ion density profiles are consistent with a galactic cosmic ray ionization source, and a constant (two body) ion recombination coefficient. Above 65 km., the ion density shows a deviation upward from the cosmic ray model, indicating an additional source or sources of ionization.

L. C. Hale
D. Baker
B. J. Rubright

7. Mass Spectrometry

7.1 General Mass Spectrometry

A paper supported in part by NASA Grant NsG-134-61 has been accepted for publication in "Vacuum". The paper titled "Mercury Vapor Hazards in Vacuum Laboratories" is a study of mercury vapor concentrations resulting from accidental release of mercury vapor or spillage by ultraviolet absorption spectrometers. The results suggest that condensed vapor from damaged diffusion-pumped vacuum systems may cause far more dangerous contamination than previously suspected. Hazards resulting from spillage appear to be much less,

although not negligible. The relative effectiveness of various decontamination procedure are considered.

B. R. F. Kendall

7.2 Resolution Enhancement

The aberrations introduced on an assumed resolved spectrum can be represented by a Fourier Convolution Integral. The need for methods of treating aberrated or poorly resolved spectra has long been recognized and has led to the development of two instruments for simulating aberrations and enhancing spectra.

The first of these instruments is based on a simple consideration of Gauss' Law in an electrostatic situation. This instrument has been constructed and is now capable of performing integrations with excellent accuracy; that is, the smearing or distortion effects of various instrument factors can be studied. Present work is now centered on providing a feedback loop with associated logic networks that will enable this device to proceed from poorly resolved spectra to spectra of an order of magnitude better resolution.

M. Zabielski

7.3 Simulation of Spectrometer Aberrations

The second instrument is a time varying field device which is close to completion. Tests consisting of convoluting two simple functions are being conducted in order to eliminate some minor mechanical problems. The results of these tests, excluding the problem stated, have been satisfactory. Considerable effort is now being spent on the rectification of the alternating signal for display on a chart recorder. A network that will have a high D.C. signal to noise ratio and also a fast d.c. response to cope with fast rising

function is being constructed.

K. Whitmore

7.4 Electrical Particle Suspension

Theoretical calculations have shown that it is possible to observe Brownian motion of a very small particle (about 1 micron in diameter) at reduced pressures. To accomplish this the particle must be in a near frictionless state. Investigation has shown that a glass surface cannot be easily prepared to meet these requirements. However, methods of suspension involving electric and for magnetic fields will produce the required environment. The particular system now under consideration will coordinate an electrodynamic suspension system with an optical-electronic particle detection system in such a way that particle position will not be critically dependent on the charge on the particle and that critical dampening of particle motion after atomic impact can be achieved.

R. B. Hazelton

8. Paper Publications, etc.

The following papers have been published:

"Round Laminar Jet in an Axial Magnetic Field" by D. P. Hoult. Published in Phys. Fluids, Vol. 8, No. 1, 886-889, May 1965.

"The Reduction of Ionograms from the Bottomside and Topside" by J. R. Doupnik and E. R. Schmerling. Published in J. A. T. P., Vol. 27, No. 8, 917-941, August 1965.

"Effect of an Axial Magnetic Field on the Stability of an Axisymmetric Jet or Wake" by D. P. Hoult. Published in Phys. Fluids, Vol. 8, No. 8, 1456-1460. August, 1965.

"Helical Motion of a Sphere in the Presence of a Magnetic Field" by D. P. Hoult. Published in Phys. Fluids, Vol. 8, No. 7, 1394-1396, July 1965.

"Simple, Stable and Reliable Transistorized D. C. Amplifiers" by L. C. Hale, J. S. Nisbet and C. K. Wilk. Published in IEEE Trans. on Inst. and Mess., Vol. I M-14, No. 3, 156-159, September 1965.

"Alfven Waves in an Incompressible Medium" by D. P. Hoult. Published in Phys. Fluids, Vol. 8, No. 12, 2240-2244, December 1965.

"Electron Densities and Temperatures in the F-region from Backscatter Measurements at Arecibo" by H. C. Carlson and J. S. Nisbet. Published in Electron Density Profiles in Ionosphere and Exosphere, 470-477, North-Holland Publishing Co., 1966.

"Electron Temperature and Density Fluctuations in the Daytime Ionosphere" by J. R. Doupnik and J. S. Nisbet. Published in Electron Density Profiles in Ionosphere and Exosphere, 493-504, North-Holland Publishing Co., 1966.

"Recombination in the Nighttime F-Region from Incoherent Scatter Measurements" by J. S. Nisbet and D. McCrory. Published in Electron Density Profiles in Ionosphere and Exosphere, 530-539, North-Holland Publishing Co., 1966.

"Analogue Simulations of 'peak smearing' in Spectrometers" by B. R. F. Kendall. Published in J.Sci.Instruments, Vol. 43, 215-219, 1966.

"Sound Waves in Relativistic Magnetohydrodynamics" by R. P. Kanwal. Published in Jour. of Math. and Mech., Vol. 15, No. 3, 379-392, March 1966.

The following papers have been accepted for publication

"Electron Temperature and Density Fluctuations in the Daytime Ionosphere" by J. R. Doupnik and J. S. Nisbet, J.G.R.

"D-Region Measurements at Night Using a Parachute-borne Blunt Probe" by L. C. Hale, Proceedings of the Conference on Dir. Aero. Meas. in the Lower Ionosphere.

"Mercury Vapor Hazards in Vacuum Laboratories" by B. R. F. Kendall, Vacuum.

"High Temperature Insulating Adhesives for Vacuum Applications" by B.R.F. Kendall and M. F. Zabielski, Journal of Vac. Sci. and Tech.

"First Order Corrections to D Region Probe Theory" by D. P. Hoult and T. J. Kuo, J.G.R.

"Apparatus for Teaching and Research in Electron Physics" by B. R. F. Kendall and H. M. Luther, American Journal of Physics.

"Dispersive Waves in the Upper Atmosphere" by D. P. Hoult, Proceedings of Seventh International Space Science Symposium, Vienna, Austria, May 1966.

"Parameters of the Low Ionosphere at Night Deduced from Parachute Borne Blunt Probe Measurements" by L. C. Hale, Proceedings of Seventh International Space Science Symposium, Vienna, Austria, May 1966.

"Measurements of Electron Density in the Upper Atmosphere by Propagation Measurements between Sections of a High Altitude Rocket" by J. S. Nisbet and J. Widmaier, Proceedings of Seventh International Space Science Symposium, Vienna, Austria, May 1966.

"Transmission and Reflection of Electromagnetic Waves Normally Incident on a Warm Plasma" by Craig Comstock, Physics of Fluids.

"Mass Spectrometry Without Ions" by B. R. F. Kendall, Proceedings of Annual ASTM E-14 Conference on Mass Spectrometry, Dallas, Texas, May 22-27, 1966.

"Constant Momentum Mass Spectrometry for Ionospheric Investigations" by H. M. Luther and B. R. F. Kendall, Proceedings of Annual ASTM E-14 Conference on Mass Spectrometry, Dallas, Texas, May 22-27, 1966.

The following Scientific Reports have been issued:

No. 247. "A Subsonic D-Region Probe Theory and Instrumentation" by L. C. Hale, D. P. Hoult, August 31, 1965.

No. 251. "Notes on Magnetohydrodynamics - Part II" by R. P. Kanwal, September 30, 1965

No. 257. "Transmission and Reflectionof Electromagnetic Waves Normally Incident on a Warm Plasma" by C. Comstock, December 10, 1965.

No. 260. "The Theory and Experimental Results of an Ionospheric Probe Experiment" by D. J. Hoffman, January 10, 1966.

No. 263. "Electron Density and the Electric Field in a Steady State F-Layer" by Craig Comstock, January 16, 1966.

The following papers were presented at scientific meetings:

"D-Region Probe Theory" by D. P. Hoult. Presented at the "Second Conference on Direct Aeronomic Measurements in the Lower Ionosphere", University of Illinois, Urbana, Illinois, September 27-30, 1965.

"D-Region Measurements at Night Using a Parachute-borne Blunt Probe" by L. C. Hale. Presented at the Second Conference on Direct Aeronomic Measurements in the Lower Ionosphere", University of Illinois, Urbana, Illinois, September 27-30, 1965.

"High-Temperature Insulating Adhesives for Vacuum Applications" by B. R. F. Kendall and M. F. Zabielski. Presented at the 12th Annual Meeting of the American Vacuum Society, New York, N.Y. September 29-October 2, 1965.

"Alfven Waves in an Incompressible Medium" by D. P. Hoult. Presented at the American Physical Society Meeting, Cleveland, Ohio, November 26, 1965.

"IRL Program and Conjugate Photo Electron Effects" by A. H. Waynick. Presented at Arecibo Ionospheric Observatory Seminar, Arecibo, Puerto Rico, December 2, 1965.

"IRL Program and Conjugate Photo Electron Effects" by A. H. Waynick. Presented at William and Mary College Seminar, Williamsburg, Virginia, December 10, 1965.

9. Personnel

Nisbet, J. S. Ph.D. Penn State 1960	Part-time	Assoc. Prof. E.E.
Hoult, D. P. Ph.D. Cal. Tech. 1962	Part-time	Assoc. Prof. Aero
Kendall, B.R.F. Ph.D. U. of Western Aust. 1960	Part-time	Assoc. Prof. Phys.
Hale, L. C. Ph.D. Carnegie Tech. 1958	Part-time	Asst. Prof. E.E.
Comstock, C. Ph.D. Harvard 1964	Part-time	Asst. Prof. Math
Carson, B. H. Ph.D. Penn State 1965	Part-time	Asst. Prof. Aero
Kuo, T. Ph.D. Candidate in Aero	1/2 time	Grad. Asst.
Widmaier, J. C. Ph.D. Candidate in E.E.	1/2 time	Grad. Asst.
McCrory, D. R. M.S. Candidate in E.E.	1/2 time	Grad. Asst.
Doupnik, J. R. Ph.D. Candidate in E.E.	1/2 time	Grad. Asst.
Luther, H. M. M.S. Candidate in Physics	1/2 time	Grad. Asst.
Kwei, M. W. Ph.D. Candidate in E.E.	1/2 time	Grad. Asst.
Pontano, B. A. M.S. Candidate in E.E.	1/2 time	Grad. Asst.
Stevenson, T. E. M.S. Candidate in E.E.	1/2 time	Grad. Asst.

Warner, R. D. M.S. Candidate in Physics	1/2 time	Grad. Asst.
Basrur, S. N. Ph.D. Candidate in Aero	1/2 time	Grad. Asst.
Zabielski, M. F. M.S. Candidate in Physics	1/2 time	Grad. Asst.
Whitmore, K. M.S. Candidate in Physics	1/2 time	Grad. Asst.
Hazelton, R. B. M.S. Candidate in E.E.	1/2 time	Grad. Asst.